Alaska Fire Science Consortium

WEBINAR SUMMARY

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WEBINAR PRESENTER:

Presenter Phillip Higuera, Paleoecology and Fire Ecology Lab PI, U. Idaho

STUDIES FROM:

Jennifer Barnes, NPS

Paul Duffy, Neptune Inc.

Feng Sheng Hu, U. Illinois

Melissa Chipman, U. Illinois

Ryan Kelly, U. Illinois

Adam Young, U. Idaho

Tundra burning in Alaska: Rare event or harbinger of climate change?

Rapid environmental change is expected in the Arctic in the coming decades. Studies have documented increases in summer warmth[1] which has contributed to shrub expansion in the region[2]. This temperature increase and change in fuel type could be creating the perfect environment for increased tundra burning.

To predict future tundra fire occurrence, researchers look to the past for information on what controls tundra fire regimes and the natural variability of burns. Researchers must first build an understanding of tundra fire characteristics, and then delve into future predictions.

1. Is the current level of tundra burning unprecedented?

The 2007 Anaktuvuk River Fire has been the subject of a number of studies on tundra fires and their impacts. One study[3] used lake cores to reconstruct the paleoecological history of the area to understand just how unique the fire was.

When a fire burns around a lake, charcoal, pollen and organic material collect on the surface, sink and accumulate at the lake bottom. Researchers were able to collect samples of organic material and use radiocarbon dating to reconstruct fire history, telling when fires occurred and what types of vegetation were present.

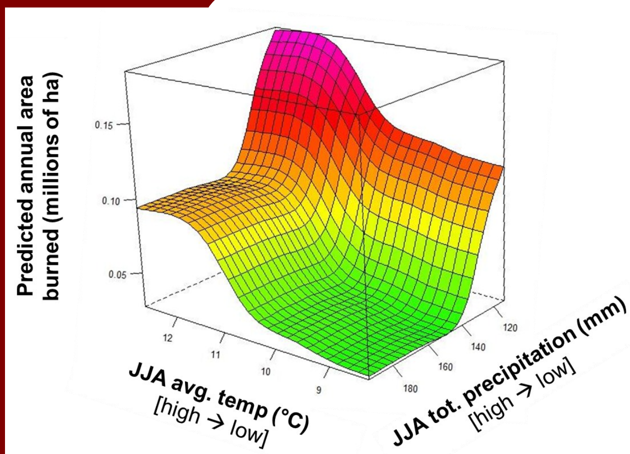
Limiting the historical window to the last 5,000 years revealed the only significant evidence of fire in the area was from the 2007 Anaktuvuk River Fire. This was pretty clear evidence that such a fire was unprecedented, at least within the last 5,000 years[3].

Collecting deeper sediments using this methodology revealed a larger history. Researchers in an ongoing study found evidence within the last 10,000 years of at least two more large fires in the region (north of the Brooks Range), suggesting fires like the Anuktuvuk River Fire are not completely unprecedented but rare[3].

Tundra burning in Noatak National Preserve (NPS Staff).

Climate Change Connections: Records show 2007 conditions were consistent with a pattern of warming—record-setting levels of low sea ice extent, low moisture and high temperatures[3, 4]. The next step was to determine whether those unusual climate conditions could explain tundra fires across the state. Time series models of area burned showed support for the concept that warm, dry growing seasons are strongly associated with the occurrence of tundra fires[3].

Paul Duffy's continued work with climate/fire models have also shown a strong correlation between temperature, precipitation and area burned, specifically indicating that area burned increases directly with either an increase in temperature or an



Models show there is a "safety zone" where temperature and precipitation can change quite a bit with no change in area burned. This three-dimensional graph demonstrates the non-linear relationship between area burned, temperature and precipitation.

increase in precipitation. There is a "safety zone" where temperature or precipitation can change quite a bit with no change in area burned. However, there is a certain threshold that, if crossed, results in large changes in area burned in response to a relatively small change in temperature or precipitation-- around 11 degrees Celsius for temperature and 140 mm for precipitation[3]. It is necessary to determine how robust these thresholds are and if and when we will cross these thresholds in the future.

Surprise! Analysis showed a moderate but *significant* relationship between sea ice extent and area burned. Models showed a correlation between decrease sea ice and increase in area burned in tundra regions since late 1970s[3].

While correlation does not mean causation, both sea ice extent and area burned were responding to a third variable, primarily temperature. Recent modeling work suggests there is reason to expect reduced sea ice extent to increase the probability of tundra burning, particularly on the North Slope, and it has to do with feedbacks from the ocean. The ocean is now a darker color, due to the loss of ice, and is therefore absorbing a lot more energy. That increased energy doesn't just affect the ocean. The heat penetrates inland, possibly **upwards of 1500 km**[5]. As sea ice continues to decline, as predicted, the warmer Arctic Ocean and warmer North Slope will increase the frequency of these warm, dry years, which are expected to coincide with occurrence of fire.

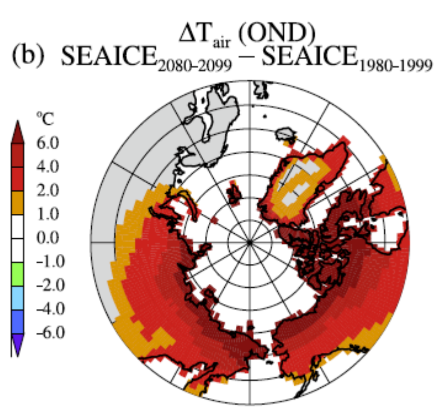
Predictions of sea ice extent, although uncertain, suggest the Arctic Ocean could be free of summer sea ice completely within a few decades, perhaps by 2038[6]. This reduction in sea ice could be a potent driver of fire conditions in the region.

2. What controls tundra burning?

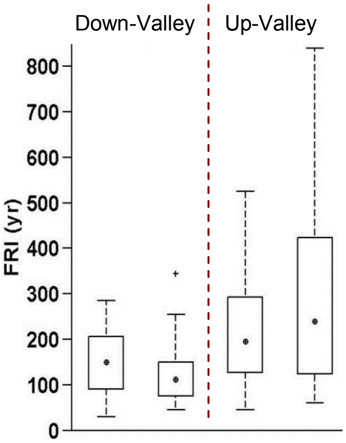
Researchers collected sediment records from four lakes in the Noatak National Preserve, an area known to have burned frequently in the last 50 years. Two lakes were in an up-valley gradient and two in down-valley locations. The down-valley sites were generally warmer and dryer, and the up-valley sites had more shrub dominance. Sediment samples showed clear evidence of frequent burning in the area going back ~6,000 years [7, 8].

Another notable find is that the two down-valley sites had more fires than the two up-valley sites. In other words, the warmer, dryer down-valley sites burned more frequently (with shorter Fire Return Intervals, or FRIs, varying from 100-400 years) than the up-valley sites with cooler temperatures and higher moisture levels. Clearly climate was a factor—warmer, drier conditions are more conducive to burning— but vegetation conditions also played a role. Pollen records from the lakes suggest vegetation changes were significantly correlated with fire frequency[7]. Sediment history revealed strong correlations between grasses and shrub birch and fire occurrence, suggesting that fire frequency changes with the abundance and type of vegetation[7].

Work by David Lawrence suggests heat absorbed by the ocean can penetrate inland upwards of 1500 km[5].



Ancient Past (13,000 to 9,000 Years Ago): There were periods when Alaska was dominated by herb tundra and experienced little fire activity, similar to the North Slope today.



Warmer, drier down-valley sites burned more frequently than cool, moist up-valley sites[3].

There was also a period dominated by shrub tundra, birch in particular, which burned frequently, statistically similar to the two down-valley sites in Noatak and sites in modern boreal forest: 100-300 year FRIs.

3. What can we expect in the future?

Tundra fires are biased toward warm, dry regions. Tundra fires can occur in regions where it is wet, but it has to be extremely warm, and likewise in areas that are relatively cool, but it has to be notably dry (Young et al, ongoing work).

Data regarding where fires occur in the modern landscape can offer predictions for future climatologies. Most models are predicting increases in moisture and increases in temperature which could put much more of Alaska in fire-prone zones. This suggests a lot more tundra will be in flammable climate space.

Paul Duffy's models for statewide tundra are predicting an overall increase in average area burned, but, at this point, individual model predictions aren't showing a substantial increase in large fire years. *This is ongoing work.* Among other things, the role vegetation must be considered.

Impacts of Tundra Burning: Work by Michelle Mack and others[9] highlights the role of tundra fires in releasing carbon. If events like the Anuktuvuk River Fire become more frequent in the future, they will play an increasingly significant role in the carbon cycle.

Tundra burning also interacts with thermokarst and permafrost melting. Tundra burning and permafrost subsidence can also affect vegetation changes, such as increased shrub expansion, which can impact wildlife habitat[10]. Since tundra fires can consume lichen, an increase in tundra burning is of relevance to wildlife managers because it can have a significant impact on caribou herds that rely on lichen for forage.

Take Home Messages:

1. Diverse tundra fire regimes suggest diverse responses and impacts. We shouldn't expect a singular response from tundra or a single impact. Responses we see from the Anuktuvuk River Fire, for example, may not reveal what we should expect to see in Noatak.
2. Tundra burning is associated with warm, dry conditions, but the paleoecological records suggest there are also important interactions with vegetation. As we think about the future we should expect some feedbacks involving vegetation.
3. Evidence increasingly suggests that Arctic environmental change will favor tundra burning with potential surprises.

Harbinger of Climate Change?

Studies suggest yes, but the EXTENT of the relationship is up for debate.

Tundra fires are rare in some regions but increased burning is consistent with impacts of a warming climate. Whether or not tundra fires are an indication of climate change will only be determined as we see what happens over next several decades. If burning events increase on the North Slope and Noatak in coming decades, as evidence of climate warming suggests may happen, we should suspect within our lifetime we'll be able to see the truth and/or extent of this relationship.

Questions

Q: With melting polar ice is it conceivable that increased open water could lead to an increase in atmospheric moisture and temperatures, leading to more instability, hence more lightning and ignitions?
A: Yes. Certainly greater atmospheric instability could lead to more lightning. It is reasonable to think increased ignitions on the North Slope will be important in the future.

Q: Tundra fires are fairly susceptible to precipitation because they are a fuels driven system, so even light rain could slow or reduce a fire. What will happen if the precipitation increases as predicted?
A: The key with increases in precipitation is that they're coming coupled with increased temperatures. If we look at moisture balance, which integrates both temperature and precipitation, it's reasonable to believe that the increase in precipitation is not going to be enough to overcome the increase in temperature. If temperature increases enough to evaporate the precipitation we're still going to end up with dryness.

Q: Could the difference in fire return intervals (FRI) between Anuktuvuk and Noatak be related to sea ice? Sea ice historically has not been a factor in the Noatak FRI. If so, might that indicate that we can expect a FRI in northern tundra similar to Noatak with sea ice reduction?
A: Interesting. It is uncertain how far south we can potentially expect sea ice loss in the Arctic Ocean to influence tundra burning. There is consideration and a potential for future study.

Q: You mentioned the importance of sea ice and stored heat. Are boreal forests also being influenced by loss of sea ice? Based on statement that ocean heat can transfer 1500 km inland we could predict some warming in central AK could be linked to sea ice loss.
A: Currently we don't have much data there but that would be an interesting thing to research.

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